# INSTRUCTION MANUAL

# MODEL 600B

# ELECTROMETER

## WARRANTY

We warrant each of our products to be free from defects in material and workmanship. Our obligation under this warranty is to repair or replace any instrument or part thereof which, within a year after shipment, proves defective upon examination. We will pay domestic surface freight costs.

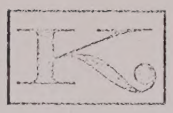
To exercise this warranty, call your local field representative or the Cleveland factory, DDD 216-248-0400. You will be given assistance and shipping instructions.

## REPAIRS AND RECALIBRATION

Keithley Instruments maintains a complete repair service and standards laboratory in Cleveland, and has an authorized field repair facility in Los Angeles and in all countries outside the United States having Keithley field representatives.

To insure prompt repair or recalibration service, please contact your local field representative or the plant directly before returning the instrument.

Estimates for repairs, normal recalibrations, and calibrations traceable to the National Bureau of Standards are available upon request.



KEITHLEY INSTRUMENTS, INC.

This preliminary Instruction Manual for the Model 600B is supplied to permit earliest possible delivery of your instrument.

It contains schematics and all the instructions necessary for operating the instrument. The final edition will contain information needed to maintain and calibrate the instrument.

Please detach, fill out and return the Warranty Card attached to the instrument. This card will enable us to send you the final edition by first class mail as soon as it is ready. The final manual can not be shipped if the card is not received.

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TABLE 1. Keithley Model 600B Specifications.

AS A VOLTMETER:
RANGE: 0.1 volt full scale to 10 volts in seven 1x and 3x ranges.
ACCURACY: ±2% of full scale on all ranges exclusive of noise and drift.
ZERO DRIFT: Less than 2 millivolts per 24 hours, less than 200 microvolts per °C, after 30-minute warm-up.
INPUT IMPEDANCE: Greater than $10^{14}$ ohms shunted by 20 picofarads. Input resistance may also be selected in decade steps from 10 to $10^{11}$ ohms.

AS AN AMMETER:
RANGE: $10^{-13}$ ampere full scale to 0.3 ampere in twenty-six 1x and 3x ranges.
ACCURACY: ±3% of full scale on 0.3 to $10^{-10}$ ampere ranges using the smallest available multiplier setting; ±5% of full scale on 3 x $10^{-11}$ to $10^{-13}$ ampere ranges.
METER NOISE: Less than $\pm 10^{-14}$ ampere.
OFFSET CURRENT: Less than 2 x $10^{-14}$ ampere.

AS AN OHMMETER:
RANGE: 1000 ohms full scale to $10^{13}$ ohms in twenty-one linear 1x and 3x ranges.
ACCURACY: ±4% of full scale on 1000 to $10^{8}$ ohm ranges using the largest available multiplier setting; ±5% of full scale on 3 x $10^{8}$ to $10^{13}$ ohm ranges.

AS A COULOMBMETER:
RANGE: $10^{-12}$ coulomb full scale to $10^{-6}$ coulomb in thirteen 1x and 3x ranges.
ACCURACY: ±5% of full scale on all ranges. Drift due to offset current does not exceed 2 x $10^{-14}$ coulomb per second.

AS AN AMPLIFIER:
INPUT IMPEDANCE: Greater than $10^{14}$ ohms shunted by 20 picofarads. Input resistance may also be selected in decade steps from 10 to $10^{11}$ ohms.
OUTPUTS: Unity-gain output and either voltage or current recorder output.
UNITY-GAIN OUTPUT: At dc, output is equal to input within 25 ppm, exclusive of noise and drift. Up to 0.1 milliampere may be drawn. Output polarity is the same as input polarity.
VOLTAGE RECORDER OUTPUT: ±1 volt for full-scale input. Internal resistance is 910 ohms. Output polarity is opposite input polarity.
Gain: 0.1, 0.33, etc. to 100.
Frequency Response (within 3 db): dc to 50 kHz at a gain of 1 and lower, decreasing to dc to 1 kHz at maximum gain. Full output response limited to 3 kHz on any gain.
Noise: Less than 1% rms of full scale at gain of 100, decreasing to less than 0.1% at gains below 10.
CURRENT RECORDER OUTPUT: ±1 milliampere for full scale input, variable ±5% with 1400-ohm recorders.

GENERAL:
POLARITY: Meter switch selects left zero (positive or negative) or center-zero scales. Output polarity is not reversed.
CONNECTORS: Input: Teflon insulated UHF type. Outputs: Barrier strip.
BATTERY CHECK: Condition of all batteries may be checked with front panel controls.
BATTERIES: Four 2N6 (or 246, VS305, NEDA 1602); one RM-1W. 700 hours battery life.
DIMENSIONS, WEIGHT: 10-1/4" high x 6-1/2" wide x 6-1/2" deep; Net weight, 7-1/4 pounds.

ACCESSORIES SUPPLIED: Mating input connector.

# SECTION 1. GENERAL DESCRIPTION

## 1-1. GENERAL.

a. The Keithley Model 600B Electrometer is an economical, completely solid-state battery operated instrument which measures a wide range of dc voltage, current, resistance and charge. The Electrometer's input resistance of greater than $10^{14}$ ohms is the result of extensive instrument development with high input impedance transistors. The Model 600B has all the capabilities of conventional VTVM's, but it can also make many more measurements without circuit loading.

b. The Electrometer has seven voltage ranges from 0.01 volt full scale to 10 volts, twenty-six current ranges from $10^{-13}$ ampere full scale to 0.3 ampere, twenty-one linear resistance ranges from 1000 ohms full scale to $10^{13}$ ohms, and thirteen charge ranges from $10^{-12}$ coulomb full scale to $10^{-6}$ coulomb.

c. The Model 600B employs matched insulated-gate field-effect transistors followed by a differential transistor amplifier and a complimentary output stage. A large amount of negative feedback is used for stability and accuracy.

## 1-2. FEATURES.

a. An important feature of the Model 600B is its excellent zero stability which permits accurate measurements with a minimum of adjustment. Zero drift with time is less than 2 mV per day. Zero offset due to temperature change is less than 200 microvolts per $^{o}C$, after a 30-minute warm-up. This offset, however, can easily be compensated for with the front-panel zero controls.

b. Fast warm up is an inherent characteristic of this Electrometer. It can be used well within 30 minutes of a cold start on the most sensitive range and almost immediately on less sensitive ranges.

c. Low offset current — less than $2 \times 10^{-14}$ ampere — minimizes zero offset with high source resistances and permits maximum resolution when measuring current and charge.

d. The 700-hour life of the batteries enables usage in long-term experiments without interruptions for replacement. Battery life is maintained even when the 1-milliampere recorder output is used. For further convenience, battery condition is readily checked on the panel meter.

e. Excellent overload protection without degradation of performance is obtained by use of a unique input circuit. The Model 600B Electrometer will withstand overloads up to 500 volts on most ranges without damage and has good recovery.

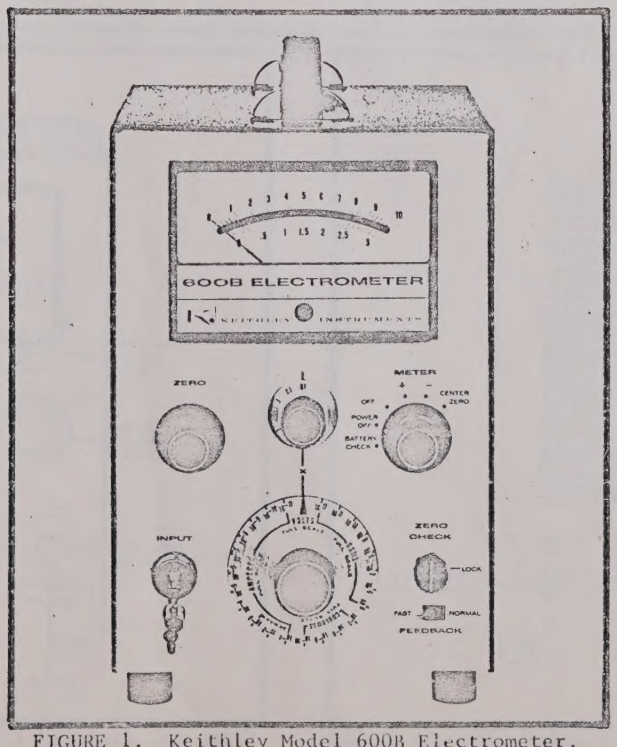



FIGURE 1. Keithley Model 600B Electrometer.

TABLE 2. Model 600B Front Panel Controls and Terminals. (Figure 2).

| Control | Functional Description | Paragraph |
|---|---|---|
| Range Switch | Selects the mode which is to be measured: voltage, current, resistance or charge. | |
| MULTIPLIER Switch | Determines full-scale voltage sensitivity, and can be used to multiply current, resistance and charge ranges on the Range Switch. | |
| METER Switch | Checks battery condition; turns instrument off; disconnects meter; selects meter polarity, sets instrument for center zero operation. | |
| ZERO Control | Allows precise meter zeroing. | |
| ZERO CHECK Button | Zeroes meter on any range | |
| FEEDBACK Switch | Determines the feedback connections within the instrument. | |
| INPUT Receptacle | Connects input to source. Receptacle is a Teflon-insulated UHF connector. | |
| Binding Post | Provides connection to ground. | |

TABLE 3. Model 600B Rear Panel Controls and Terminals. (Figure 3)

| Control | Functional Description | Paragraph |
|---|---|---|
| COARSE ZERO Switch | Extends the zeroing capability of the front panel ZERO Control. | |
| 1 V - 1 MA CAL Control | Varies voltage and current output ±10%. | |
| Barrier Strip Connector (X1, OHMS GUARD, A, B and GND Terminals) | Connection to voltage/current output, unity-gain output, guard and case ground terminals. | |

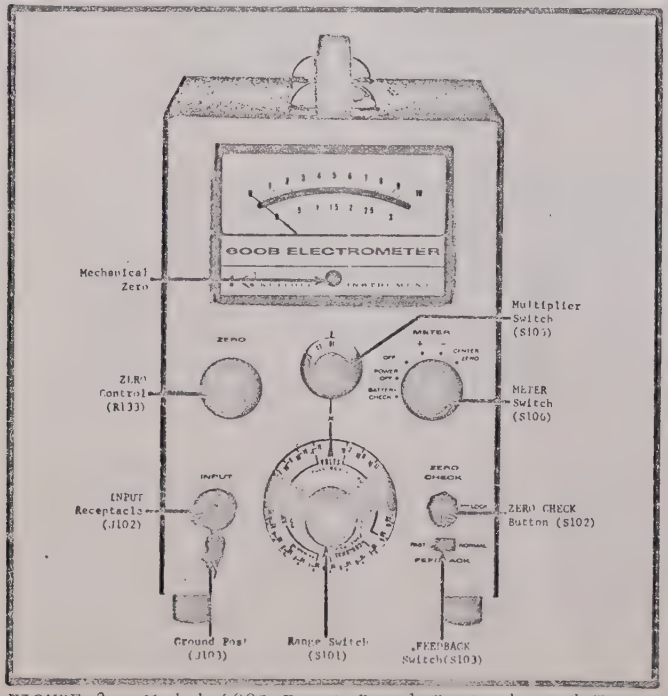



FIGURE 2. Model 600B Front Panel Controls and Terminals.

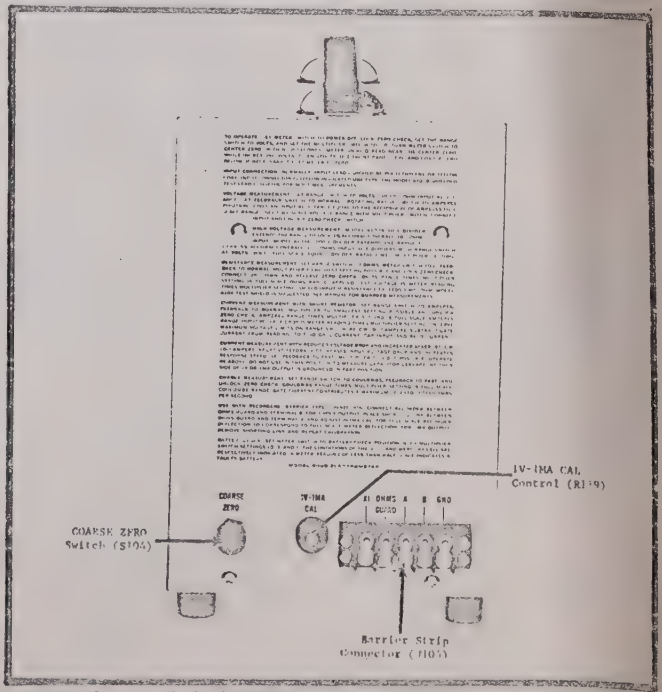



FIGURE 3. Model 600B Rear Panel Controls and Terminals.

# SECTION 2. OPERATION.

2-1. INPUT CONNECTIONS. The Model 600B INPUT Receptacle is a Teflon-insulated UHF connector. A shield cap is provided. The ground post, below the Receptacle, is connected to chassis ground.

a. The accessories described in Section 7 are designed to increase the accuracy and convenience of input connections. Use them to gain the maximum capability of the Model 600B.

NOTE

Techniques and applications are thoroughly discussed in the brochure, Electrometer Measurements, by Joseph F. Keithley. It is available from Keithley Instruments, Inc., or its representatives.

b. When working with a high impedance source carefully shield the input connection and the source since any variation in the electrostatic field near the input will cause definite meter disturbances.

c. Use high resistance, low-loss materials — such as Teflon (recommended), polyethylene or polystyrene — for insulation. Insulation leakage resistance of test fixtures and leads should be several orders of magnitude higher than the internal resistance of the source. Excessive leakage reduces the accuracy of reading from high impedance sources. Coaxial cables used should be a low noise type which employ a graphite or other conductive coating between the dielectric and the surrounding shield braid. Amphenol-Borg Electronics Corp., Microdot, Inc., and Simplex Wire and Cable Co. make satisfactory types. The supplied Input Cable insures good input connections.

NOTE

Clean, dry connections and cables are very important to maintain the value of all insulation materials. Even the best insulation will be compromised by dust, dirt, solder flux, films of oil or water vapor. A good cleaning agent is methyl alcohol, which disolves most common dirt without chemically attacking the insulation. Air dry the cables or connections after washing with alcohol or use dry nitrogen if available. Or, if available, Freon is an excellent cleaning agent.

d. When working with a high impedance source any change in shunt capacitance of the input circuit will cause disturbances in the reading. Make the measuring setup as rigid as possible, and tie down connecting cables to prevent their movement. A continuous vibration may appear at the output as a sinusoidal signal, and other precautions may be necessary to isolate the instrument and connecting cable from the vibration.

e. For low impedance measurements — below $10^8$ ohms or above $10^{-8}$ ampere — unshielded leads may be used and a binding post adapter may be used. However, keep the leads short.

f. When the Model 600B is used on the most sensitive current range with the FEEDBACK Switch at FAST, some insulators — such as Teflon — may produce random signals which show up as erratic meter deflections. Insulation used in the Model 600B is carefully selected to minimize these spurious signals.

g. If a well shielded chamber and a well made high impedance transfer switch is available it is advantageous to connect the Model 600B to the circuit only when a reading is being made. In some cases, the offset current can charge the external test circuitry. One example of this occurs when measuring a capacitor's leakage resistance by observing the decay of the terminal voltage. If the leakage current is less than the offset current (less than $2 \times 10^{-14}$ ampere), there may be no decay of the terminal voltage when the Electrometer is left connected across the capacitor's terminals.

NOTE

Keep the shield cap on the INPUT Receptacle when the Electrometer is not in use.

2-2. PRELIMINARY PROCEDURES.

a. Check battery condition by holding the METER Switch in the BATTERY CHECK position. Turn the Multiplier Switch to 10, 3 and 1 position and observe the meter readings. The meter should read one-half of full scale or more in each Multiplier Switch position. Table 4 shows the batteries checked by each position. If the reading for any battery is below one-half full scale, replace the indicated battery.

BATT. TEST

TABLE 4.

Multiplier Switch Positions for Checking Conditions of Batteries.

| Multiplier Position | Battery Checked |
|---|---|
| 10 | BA103 & BA104 |
| 3 | BA101 & BA102 |
| 1 | BA105 |

b. Set the controls as follows:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | VOLTS |
| Multiplier Switch | 1 |
| FEEDBACK Switch | NORMAL |
| METER Switch | POWER OFF. |

c. Turn the Meter Switch to CENTER ZERO. Within ten seconds, the meter needle should come to the cen-

ter zero position. If not, adjust the meter zero with the front panel ZERO Control. Normally, there is no need to use the COARSE ZERO Switch.

NOTE

Using the center zero scales decreases accuracy 0.5% because the scale span is reduced.

d. After a few moments increase the voltage sensitivity by advancing the Multiplier Switch to .3, .1, etc. Continue zeroing with the ZERO Control.

e. After long periods of storage or after an overload, the Model 600B may drift excessively. The input transistors are insensitive to mechanical shock; however, a severe input overload may cause a zero offset. This is corrected with the Zero Controls. Drifting, though, can occur for several hours.

f. Although the offset current of the Electrometer is much below that found in conventional voltmeters, it can be observed on the meter. The current charges the input capacitance, and the Electrometer appears to drift when the input is open. Use the ZERO CHECK Button to discharge the charge build-up. Depressing the ZERO CHECK Button removes all signal from the amplifier.

g. Follow the particular procedures in paragraphs 2-3 to 2-6 for measuring voltage, current, resistance and charge.

2-3. VOLTAGE MEASUREMENTS.

a. The Model 600B;s high input impedance allows circuit measurements without causing circuit loading. For low resistance in-circuit tests, the input resistance can be lowered to avoid pick-up problems.

NOTE

Make all voltage measurements with the FEEDBACK Switch only in the NORMAL position.

b. High Impedance Measurements ($10^{14}$ ohms, 20 picofarads). Follow the instructions of paragraph 2-2. Set the controls as follows:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | VOLTS |
| Multiplier Switch | 10 |
| FEEDBACK Switch | NORMAL |
| METER Switch | CENTER ZERO |

Connect the unknown source to the INPUT Receptacle and unlock the ZERO CHECK Button. Set the METER Switch to + or -, as necessary. Increase the sensitivity with the Multiplier Switch. Recheck the zero setting after increasing the sensitivity.

c. Low Impedance Measurements. To decrease the input resistance from $10^{14}$ ohms, set the Range Switch to one of the AMPERES ranges. The input resistance is now the reciprocal of the current range. For instance, to obtain an input resistance of $10^{7}$ ohms — which is normal for conventional VTVMs — set the Range Switch to $10^{-7}$ AMPERES range. Set the full-scale voltage range with the Multiplier Switch. Operating procedures are the same as subparagraph b above.

d. To measure sources more than 10 volts, use the Model 6102A 10:1 Divider Probe or the 6103A 1000:1 Divider Probe. The Model 6102A extends the Model 610B's range to 100 volts; overall accuracy is $\pm 4\%$ and input resistance is $10^{10}$ ohms. The Model 6103A extends the Model 610B's range to 10 kilovolts; overall accuracy is $\pm 6\%$ and input resistance is $10^{12}$ ohms. Follow the same operating procedures with the dividers as in subparagraph b. The full-scale voltage range is the divider ratio times the Multiplier Switch setting.

2-6. CURRENT MEASUREMENTS.

a. The Model 600B can measure currents three ways.

1. In the normal method — used on any range — the current is determined by measuring the voltage drop across a resistor shunting the amplifier input. This method is useful when lower noise is more important than faster response speeds or if some damping is needed.

2. In the fast method — for use only below the $10^{-5}$ ampere range — the shunt resistor is between the amplifier output and input in the feedback loop. This circuit largely neutralizes the effect of input capacity and greatly increases the response speed. Also, the input voltage drop is reduced to less than one millivolt on any range.

3. For galvanometric current measurements, the Model 600B acts as a null indicator between a very accurate current source and the unknown current source.

b. Rise time varies primarily with the current range, the input capacity and the method used. With the FEEDBACK Switch in the FAST position, the rise time on the most sensitive range is less than 2.5 seconds and on the $10^{-6}$ ampere range is less than 3 milliseconds. Given a choice, it is better to place the Electrometer near to the current source than to the data reading instrument. Transmitting the input signal through long coaxial cables slightly decreases the response speed and significantly increases noise due to the cable capacitance.

c. Normal Method (0.3 to $10^{-13}$ ampere ranges).

1. Follow the instructions of paragraph 2-2. Set the controls as follows:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | $10^{-1}$ AMPERES |
| Multiplier Switch | 1 |
| FEEDBACK Switch | NORMAL |
| METER Switch | CENTER ZERO. |

Connect the unknown source to the INPUT Receptacle and unlock the ZERO CHECK Button. Set the METER Switch to + or -, as necessary. Increase the sen-

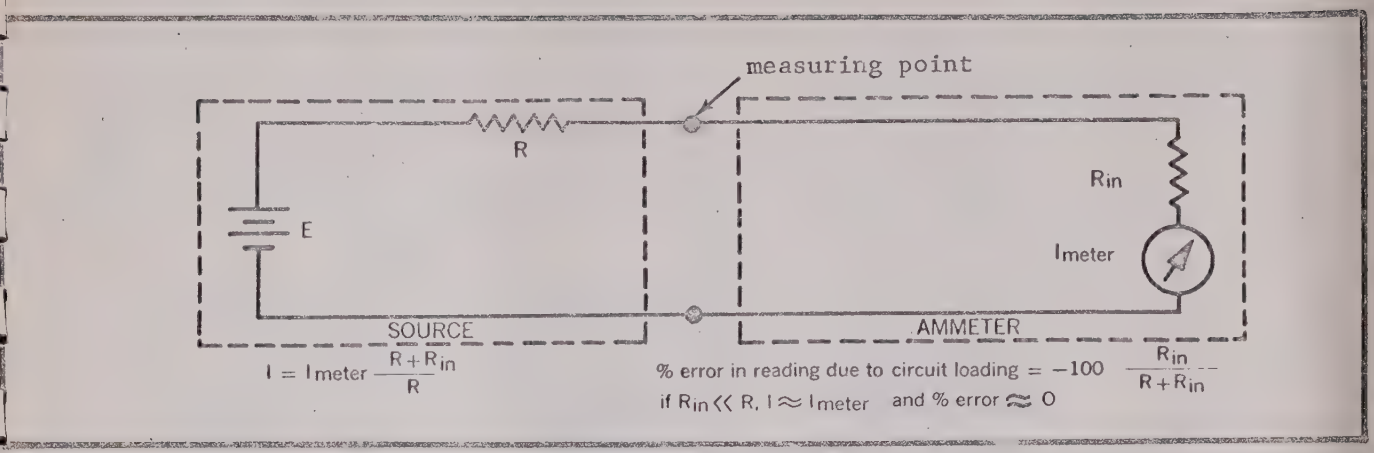



FIGURE 4. Error Due to Ammeter Resistance. Current sources may be considered a voltage (E) in series with a resistance (R). The current with the ammeter short circuited is I = E/R. With the short circuit removed, the effective input resistance of the ammeter ($R_{in}$) is in series with the source resistance (R). The current in the complete circuit is reduced and $I_{meter} = E/(R + R_{in})$. If the effective ammeter input resistance is small compared to R, $I_{meter} \sim I$ and the error introduced by circuit loading is negligible.

sensitivity with the Range Switch and the Multiplier Switch. Do not set the Multiplier Switch higher than 3 for Range Switch settings $10^{-3}$ and above. Check zero with the ZERO CHECK Button.

2. The full-scale current range is the Range Switch setting times the Multiplier Switch setting. Use the smallest Multiplier Switch setting possible to obtain the best accuracy. The input resistor varies with the Range Switch setting, from 10 ohms at $10^{-1}$ AMPERES to $10^{11}$ ohms for $10^{-11}$ AMPERES. The input voltage drop is the meter reading times the Multiplier Switch setting.

NOTE

On the low current ranges, balance out the offset current with the Zero Controls or subtract the value from the reading. To find the amount of offset current, cap the INPUT Receptacle and read the meter.

d. Fast Method (ranges below $10^{-5}$ ampere).

1. Follow the instructions of paragraph 2-2. Set the controls as follows:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | $10^{-6}$ AMPERES |
| Multiplier Switch | 1 |
| FEEDBACK Switch | FAST |
| METER Switch | CENTER ZERO. |

Connect the unknown source to the INPUT Receptacle and unlock the ZERO CHECK Button. Set the METER Switch to + or -, as necessary. Increase the sensitivity with the Range Switch and the Multiplier Switch. Do not set the Range Switch to $10^{-5}$ AMPERES or higher. Check zero with the ZERO CHECK Button. Do not short the input because this will remove the feedback from the circuit.

2. The full-scale current range is the Range Switch setting times the Multiplier Switch setting. When selecting the Multiplier Switch setting, remember small settings permit lower current source resistance, and larger settings improve instrument zero stability. Check the caution in subparagraph 3a below.

3. With the fast method, the input drop is reduced and the response speed is increased at least 100 times. However, follow these cautions:

a) The internal impedance of the unknown current should not be less than .1 of the value of the feedback resistor being used. Otherwise, the full feedback voltage cannot be developed at the input, and zero instability results. The feedback resistor value is the reciprocal of the AMPERES range of the Range Switch.

b) The OHMS GUARD Terminal of the Barrier Strip Connector is no longer connected to case ground. Therefore, do not use a grounded recorder. As an alternate, use the unity-gain output (paragraph 2-8).

c) Use, with caution, the fast method to measure capacitor leakages. A very stable voltage supply must be used. Connecting a capacitor to the input changes the circuit to a differentiator, resulting in extreme sensitivity to very small voltage transients and an increase in meter noise.

e. Galvanometric Method.

1. Operate the Model 600B as a picoammeter in the fast method. Use an accurate reference current source such as the Keithley Model 261 to buck out the unknown current source. Connect as shown in Figure 5.

2. Set the METER Switch to CENTER ZERO and use the higher current ranges. Adjust the buckout current to indicate null on the Model 600B. Increase the Electrometer sensitivity as needed. When the Model 600B is as close to null as possible, the unknown current is equal to the algebraic sum of the Model 261 setting and the Model 600B current reading.

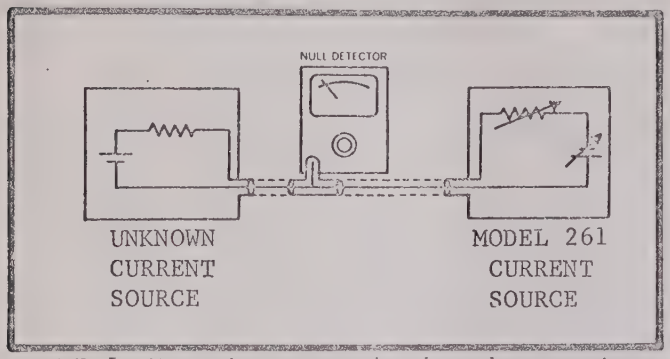



FIGURE 5. Measuring Current by the Galvanometric Method. Use an accurate reference current source to buck out the unknown current source. The Model 600B, on its current ranges, serves as a null detector. Use a UHF-tee fitting at the Model 600B input. Connect the Electrometer to the two sources with coaxial cable. Select cable carefully for very low currents (see paragraph 2-1).

2-6. RESISTANCE MEASUREMENTS.

a. The Model 600B can measure resistance by two methods.

1. In the constant current method, the Electrometer measures the voltage drop across the unknown sample as a known, constant current flows through it. The voltage drop is proportional to the resistance of the sample. In this method the Model 600B can be used in one of two different modes: normal or fast.

a) The normal mode is recommended for use from 1 kilohm to $10^{11}$ ohms.

b) Above $10^{11}$ ohms the fast method is preferred. It results in faster response speed and also nullifies leakage across the Electrometer input, since the potential across the input terminal is small.

2. In the preceding method, the voltage across the sample cannot be arbritrarily set. In some cases, as in measuring capacitor leakage, this results in excessively long testing time. In the voltmeter-ammeter method the Model 600B is used as a picoammeter. The unknown resistance sample is connected to an external known voltage source and the current through the sample is measured. Either the normal or fast method may be used. The resistance is calculated from the readings.

NOTE

Discharge any capacitor completely before removing it from the circuit. Depressing the ZERO CHECK Button shorts the input through a 10-megohm resistor, providing a discharge path.

b. Normal constant Current Method (recommended for use from 1 kilohm to $10^{11}$ ohms).

1. Set the controls as follows:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | $10^{11}$ OHMS |
| Multiplier Switch | 1 |
| FEEDBACK Switch | NORMAL |
| METER Switch | + |

Unlock the ZERO CHECK Button. Check zero only with the ZERO CHECK Button.

NOTE

Do not open circuit the Electrometer on the OHMS ranges; the input will develop up to 10 volts due to its constant current characteristic. Keep the input shorted or the ZERO CHECK Button locked.

2. The full-scale ohms range is the Multiplier Switch setting times the Range Switch setting. Use the smallest Range Switch setting possible to obtain the best accuracy.

3. Before making a final reading, manipulate the Multiplier and Range Switches, so the sample is tested at a number of test potentials. The applied test voltage is the percentage of full scale that the meter reads times the Multiplier Switch setting.

4. When the test current is applied, the high terminal of the INPUT Receptacle is positive. The test current is the reciprocal of the OHMS Range setting.

NOTE

Shield the input if the resistance sample exceeds $10^8$ ohms.

c. Fast Constant Current (Guarded) Method (recommended for use from $10^{11}$ to $10^{13}$ ohms).

1. Follow the instructions of paragraph 2-2. Set the controls as follows:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | $10^{12}$ OHMS |
| Multiplier Switch | 1 |
| FEEDBACK Switch | FAST |
| METER Switch | + |

Connect the high impedance side of the resistance sample to the INPUT Receptacle and the low impedance side to the OHMS GUARD Terminal. Unlock the ZERO CHECK Button.

2. Read the resistance as in subparagraph b2 above.

d. Voltmeter-ammeter Method (to $10^{16}$ ohms).

1. Turn the ZERO CHECK Switch to LOCK. Connect sample between INPUT Receptacle and power supply. (See Figure 6). Put a switch in the high voltage line to ground low impedance end of the sample when it is disconnected from the potential.

2. Set the FEEDBACK Switch to NORMAL. Usually this method is best, since instabilities can arise for resistance samples less than 0.1 the value of the feedback resistor.

3. To make a measurement, start with switch S as shown in Figure 6 and make sure the ZERO CHECK Button is set to LOCK. Set switch S to apply a potential across the sample for a known period of time. Then unlock the ZERO CHECK Button and take the reading. Set the Range Switch to $10^{-1}$ AMPERES and increase sensitivity until a reading is obtained.

4. To remove the sample, set the ZERO CHECK Button to LOCK and set switch S back to ground as shown in Figure 6.

5. If the potential applied is at least 100 times the full-scale input drop (Multiplier Switch setting), the resistance is equal to the applied potential divided by the current reading. The high voltage sensitivity of the Model 600B, therefore, permits external voltages of 0.1 volt or more to be used.

6. If the potential applied is less than 100 times the input drop, the resistance is equal to the difference between the applied potential and the input drop, all divided by the current reading.

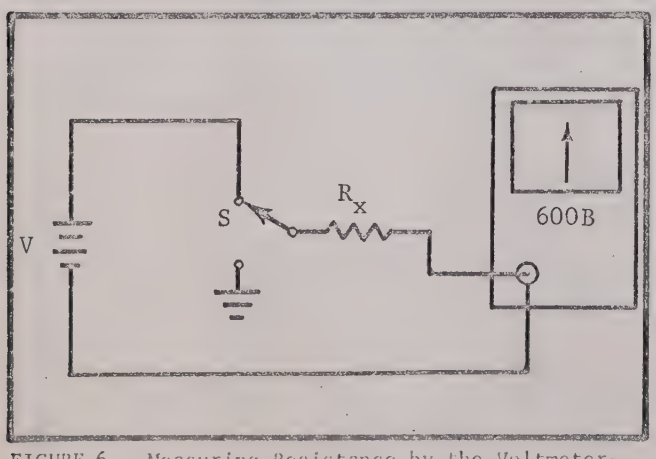



FIGURE 6. Measuring Resistance by the Voltmeter-Ammeter Method. A potential from a known source, V, is applied to the unknown resistance sample, $R_X$. The Model 600B measures the current through $R_X$, from which the resistance is calculated. Switch S connects the low end of $R_X$ to ground when no potential is applied.

7. If the current is read by the fast method, the input drop is so slight that it need not be included in the calculation. If the capacity shunted across the sample is large, such as encountered in capacitor leakage measurements, the faster method increases response speed and this connection is recommended. Note, however, that power supply transients will be magnified.

2-7. CHARGE MEASUREMENTS.

a. Follow the instructions of paragraph 2-2. Set the controls as follows:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | $10^{-7}$ COULOMBS |
| Multiplier Switch | .01 |
| FEEDBACK Switch | FAST |
| METER Switch | CENTER ZERO. |

Unlock the ZERO CHECK Button and then connect the unknown source to the INPUT Receptacle. If the Electrometer reads off scale, increase the Multiplier Switch setting. If the sensitivity is not enough, decrease the Multiplier Switch setting until the reading is on scale. Changing the Multiplier Switch setting does not affect the transfer of charge from the unknown source to the instrument. If increasing sensitivity with the Multiplier Switch does not bring the reading on scale, increase sensitivity with the Range Switch and repeat the above steps.

b. The full-scale charge range is the Range Switch setting times the Multiplier Switch setting. Input offset contributes a charge of $2 \times 10^{-14}$ coulomb per second maximum.

c. Use the ZERO CHECK Button to discharge the integrating capacitor. Discharge for at least 20 seconds on the $10^{-7}$ coulomb range before making another measurement. On the $10^{-8}$ coulomb range, discharge for at least two seconds.

2-8. RECORDER OUTPUTS.

a. The Model 600B uses a Barrier Strip Connector on its rear panel for all recorder output connections. The output of the Model 600B may be used to drive servo rebalance recorders, oscilloscope and pen recorders. The Model 600B has two recorder outputs, $\pm 1$ volt and $\pm 1$ milliampere, to amplify signals within 1/2% for recorders, oscilloscopes and similar instruments. These can be used on all ranges of the Model 600B.

b. For recording with the Model 600B, use the Keithley Model 370 Recorder for ease, economy, versatility and performance. The Model 370 is a pen recorder with 10 chart speeds and 1% linearity. Interface problems often encountered between a measuring instrument and a recorder are avoided using the Model 370. No preamplifier is needed. No special wiring is required. When using the Model 370 make sure the Recorder's sensitivity control is set to maximum (completely clockwise). (See Section 7 for more on the Model 370.)

WARNING

The Model 600B may be used with the FEEDBACK Switch in FAST position with other instruments. However, make sure there is no common ground connection between low terminals of the Electrometer and other instruments.

c. 1-Volt Output. Place the shorting link between the OHMS GUARD Terminal and Terminal A. Connect oscilloscopes and pen recorder amplifiers to the OHMS GUARD Terminal and Terminal B on the barrier strip connector. Adjust the 1V - 1MA CAL Control for full-scale recorder deflection to correspond with full-scale meter deflection. Output is 1 volt. Internal resistance is 1000 ohms. Accuracy is within 1%. The frequency response (-3db) is dc to 1kHz at a gain of 100, rising to 50kHz at gains of 1 and below. Full output response is limited to 3kHz on any gain. Noise is less than 1% rms of full scale at a gain of 100, decreasing to less than 0.1% at gains below 10. The METER Switch does not reverse the output polarity. Output polarity is opposite input polarity.

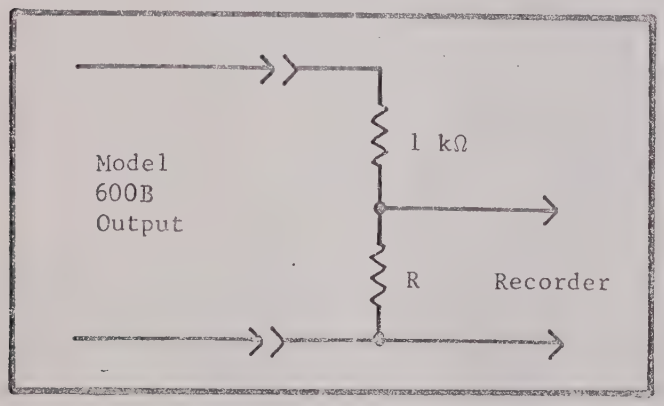



FIGURE 7. Divider Circuits Across Model 600B Output for Driving 50 and 100-millivolt Recorders. Use 5% resistors in the dividers. The value of resistor R is one ohm for every 1mV of output.

d. 1-Milliampere Output: Connect 1-milliampere instruments to the OHMS GUARD Terminal and Terminal B on the Barrier Strip Connector and remove the shorting link. The output is approximately 1 milliampere for full-scale meter deflection on any range. For exact output, adjust the meter on the .01 volt range with the ZERO Control for full-scale deflection. Then adjust the 1V - 1MA CAL Control until the recorder reads full scale. Check the recorder and meter zero and repeat adjustment if necessary. The METER Switch does not reverse the output polarity (opposite input polarity).

e. For servo rebalance recorders, use a divider of not greater than a total of 2 kilohms across the Model 600B Barrier Strip Connector. See Figure 7. Connect as for 1-milliampere output (sub-paragraph d above). Adjust as in sub-paragraph d above. Operation is the same as for current outputs.

f. When the FEEDBACK Switch is in the NORMAL position, the negative terminal of the Barrier Strip Connector is connected to the instrument case. Therefore, no difficulty will be experienced using oscilloscopes and recorders with the Model 600B set for normal operation. In FAST position, however, neither output terminal is grounded. If this is used, make sure there is no common ground between the recorder or oscilloscope and the Model 600B case, or use the unity-gain output.

2-9. UNITY GAIN OUTPUT. The unity-gain amplifier can be used as an impedance matching device to minimize circuit loading errors or for convenient connections to a recorder when the FEEDBACK Switch is in FAST position.

a. The unity-gain output is equal to the input within 25 ppm when the load resistance is 100 kilohms or greater. By placing the Model 600B between a $10^{10}$ ohm source, for example, and a 0.01% voltmeter with a 1-megohm input resistance, overall accuracy better than 0.025% can be achieved.

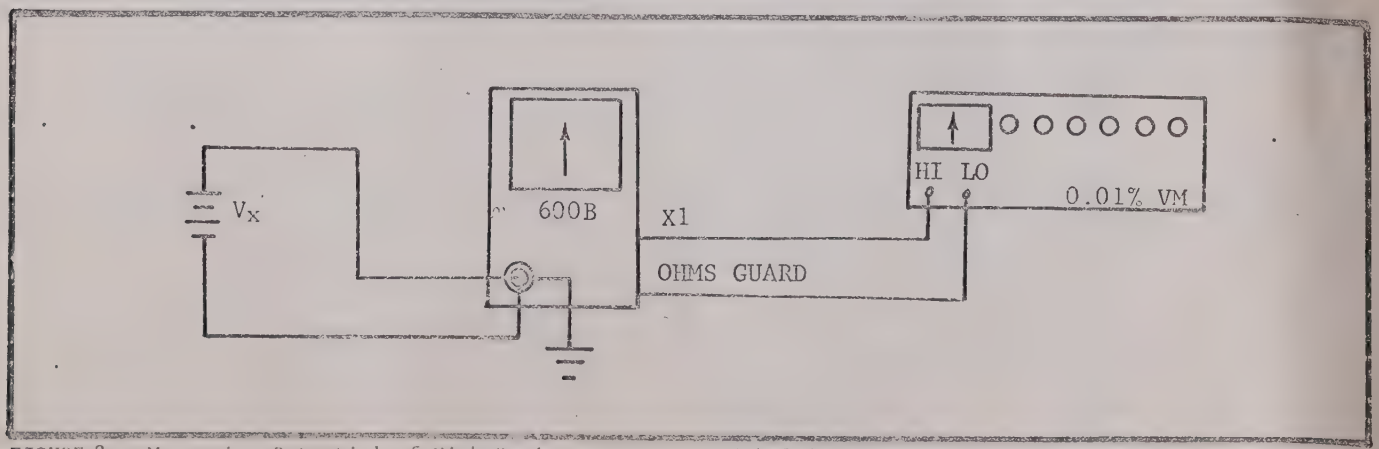



FIGURE 8. Measuring Potential of High Resistance Source with 0.025% Accuracy. The Model 600B is used between a high-resistance source, $V_X$, and a 0.01% voltmeter to obtain high accuracy without causing circuit loading. The digital voltmeter or, as above, the Keithley Model 662 Differential Voltmeter connects to the Model 600B unity-gain terminals.

1. Connect the voltmeter to the X1 and OHMS GUARD Terminals as shown in Figure 8. The OHMS GUARD Terminal is at ground with the FEEDBACK Switch in NORMAL. Maximum output amplitude is 10 volts peak-to-peak.

2. Adjust the Model 600B Zero Controls to obtain a zero-voltage reading on the external voltmeter. Make sure the latter's sensitivity is high enough for a precise zero adjustment.

b. When the FEEDBACK Switch is in FAST position, the unity-gain terminals permit more convenient connections to oscilloscopes with a load resistance of greater than 100 kilohms without special precautions. In this mode, the X1 Terminal is grounded and the OHMS GUARD Terminal delivers an output equal to the input signal.

## SECTION 3. APPLICATIONS.

3-1. GENERAL. This Section discusses some particular applications of the Model 600B that are not so common and that are not discussed in Section 2. The versatility of the Model 600B is such that it is almost a complete dc laboratory in itself. The applications mentioned here suggest uses and techniques that will increase the usefulness of the Model 600B Electrometer.

3-2. CURRENT SOURCE. The Model 600B can be used as a ±5% current source on all OHMS ranges with a compliance equal to the Multiplier Switch setting. Follow these procedures.

a. Set the FEEDBACK Switch to NORMAL, the Range Switch to OHMS and the METER Switch to +.

b. The current supplied at the INPUT Receptacle is the reciprocal of the OHMS Setting on the Range Switch. (For example, $10^9$ OHMS indicates $10^{-9}$ Ampere current at the INPUT Receptacle.)

c. The Multiplier Switch does not affect the current at the INPUT Receptacle. It does affect the maximum input voltage drop, which is equal to the percentage of full scale that the meter reads times the Multiplier Switch setting. For accurate output current, check the meter zero on the .01-volt range.

3-3. STATIC CHARGE MEASUREMENTS. Electrometers are very sensitive to static charges and can readily make qualitative or quantitative measurements.

a. Zero the Model 600B; set the FEEDBACK Switch to NORMAL and the Range Switch to VOLTS (3 or 10 volts full scale). Bring the charged object near the uncovered, unshielded INPUT Receptacle. Depending upon the distance between the charge and the instrument, a voltage will be induced on the input terminals which can be read on the meter. Check zero frequently since accumulation of charge due to the input offset current will cause a slow drift of the input voltage.

b. Connecting a capacitor across the input reduces the drift due to offset current and also the sensitivity to charge. Therefore, with the FEEDBACK Switch in NORMAL, set the Range Switch to COULOMBS position. The capacitor value connected across the input in farads is equal to the COULOMBS Range.

3-4. CAPACITANCE MEASUREMENTS. The Model 600B can measure capacitance from 500 picofards to 100 microfarads. The Electrometer charges the capacitor to a known potential and then measures the charge. The resulting capacitance is easily figured.

a. Charge the capacitor as follows:

1. Set the Model 600B front panel controls to:

| | |
|---|---|
| ZERO CHECK Button | LOCK |
| Range Switch | OHMS |
| Multiplier Switch | 0.1 to 10 |
| FEEDBACK Switch | NORMAL |
| METER Switch | + |

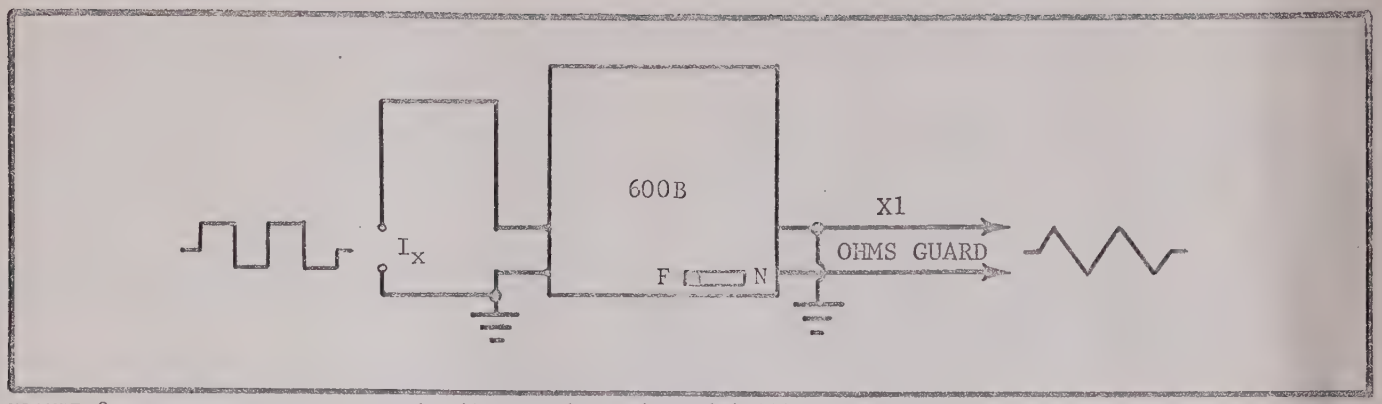



FIGURE 9. Current Integrator. The diagram shows the Model 600B acting as a current integrator. A square wave from a current source, $I_X$, is applied to the Model 600B input. Using the COULOMBS ranges, the output through the unity-gain terminals is shown.

2. Connect the unknown capacitor to the INPUT Receptacle. Unlock the ZERO CHECK Button and charge the capacitor to a known voltage. As the capacitor charges, the meter will advance up scale to show the voltage (percentage of full scale that the meter reads times the Multiplier Switch setting) across the capacitor at any given time.

3. Charge the capacitor to a convenient voltage, such as 0.1, 1, etc. The OHMS ranges control the charging rate: start with the lower ranges and increase the setting as the voltage across the capacitor approaches the desired value.

4. When the capacitor reaches the desired value, quickly disconnect the capacitor from the INPUT Receptacle. Switch the Model 600B to a convenient COULOMBS Range, set the FEEDBACK Switch to FAST and measure the charge on the capacitor following the instructions in paragraph 2-7.

b. The value of the unknown capacitance is the stored charge divided by the initial voltage:

$$C\ (\text{farads}) = \frac{Q\ (\text{Coulombs})}{V\ (\text{volts})}.$$

3-5. CURRENT INTEGRATOR. The Model 600B works as an integrator for time-varying currents. Figure 9 shows the circuit. Set the Range Switch to COULOMBS and the FEEDBACK Switch to FAST. Use the unity-gain output. The output voltage, $V_{out}$, is

$$V_{out} = \frac{1}{C}\int i\,dt$$

where C is the coulomb range setting in farads.

3-6. POTENTIOMETRIC VOLTAGE MEASUREMENTS. The high input impedance, 10-millivolt sensitivity and low zero drift make the Model 600B useful as a null detector in potentiometric voltage measurements. The circuit shown in Figure 10 is useful when no loading of the source voltage, on or off null, can be tolerated. Make the measurements with the center zero scale, following the procedures in paragraph 2-4. When the Model 600B is at null — no meter deflection — the

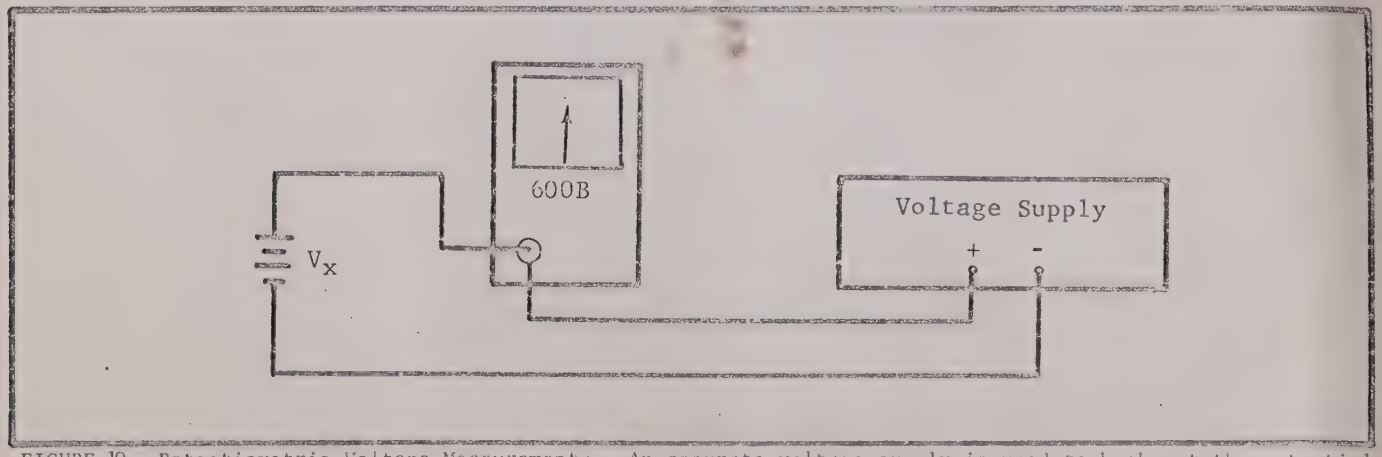



FIGURE 10. Potentiometric Voltage Measurements. An accurate voltage supply is used to buck out the potential from the unknown source, $V_X$. The Model 600B on the voltage ranges and center-zero scales acts as a null detector. Note that the unknown, $V_X$, need not be grounded if a floating voltage supply is used.

voltage from the unknown source equals the unknown source.

3-7. MEASURING DIODE CHARACTERISTICS. The Model 600B can accurately measure diode characteristics in one simple step without using any other equipment. The circuit is shown in Figure 11. The measurements are made on the OHMS ranges, selecting constant currents down to $10^{-11}$ ampere in decade steps and reading the voltage drop across the diode. The characteristic curve can then be plotted in volts and amperes or in volts and ohms. Read the voltage from the positive meter scale. The current polarity is positive out of the center terminal of the INPUT Receptacle.

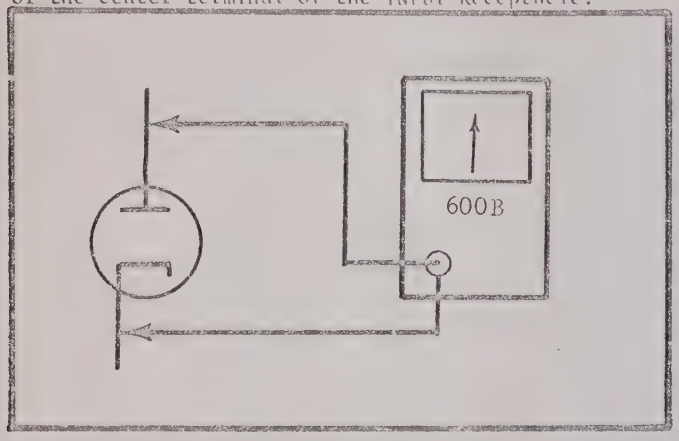



FIGURE 11. Measuring Diode Characteristics with Model 600B. Use the OHMS range of the Electrometer.

3-8. PEAK-READING VOLTMETER. The Model 600B easily converts to a peak-reading voltmeter. Set the Range Switch to the COULOMBS ranges and apply the input voltage to the INPUT Receptacle through an external diode. In the circuit shown in Figure 12, if the input resistance ($R_i$) and diode leakage resistance ($R_d$) are high and if the time constant of the RC combination is high compared to the period of the signal, the capacitor will charge to the peak value of the applied ac voltage minus the small drop across the diode. The Model 600B input resistance on the VOLTS or COULOMBS ranges is $10^{14}$ ohms or greater, and may therefore be neglected compared to the leakage resistance of most diodes. The capacitor (C) is selected using the COULOMBS ranges with the FEEDBACK Switch in the NORMAL position. C in farads is equal to the COULOMBS range setting.

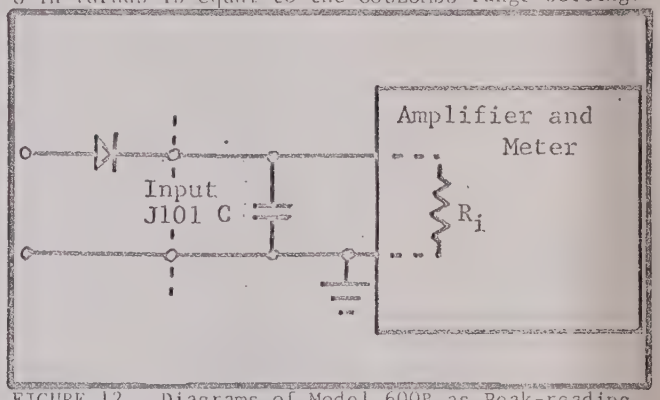
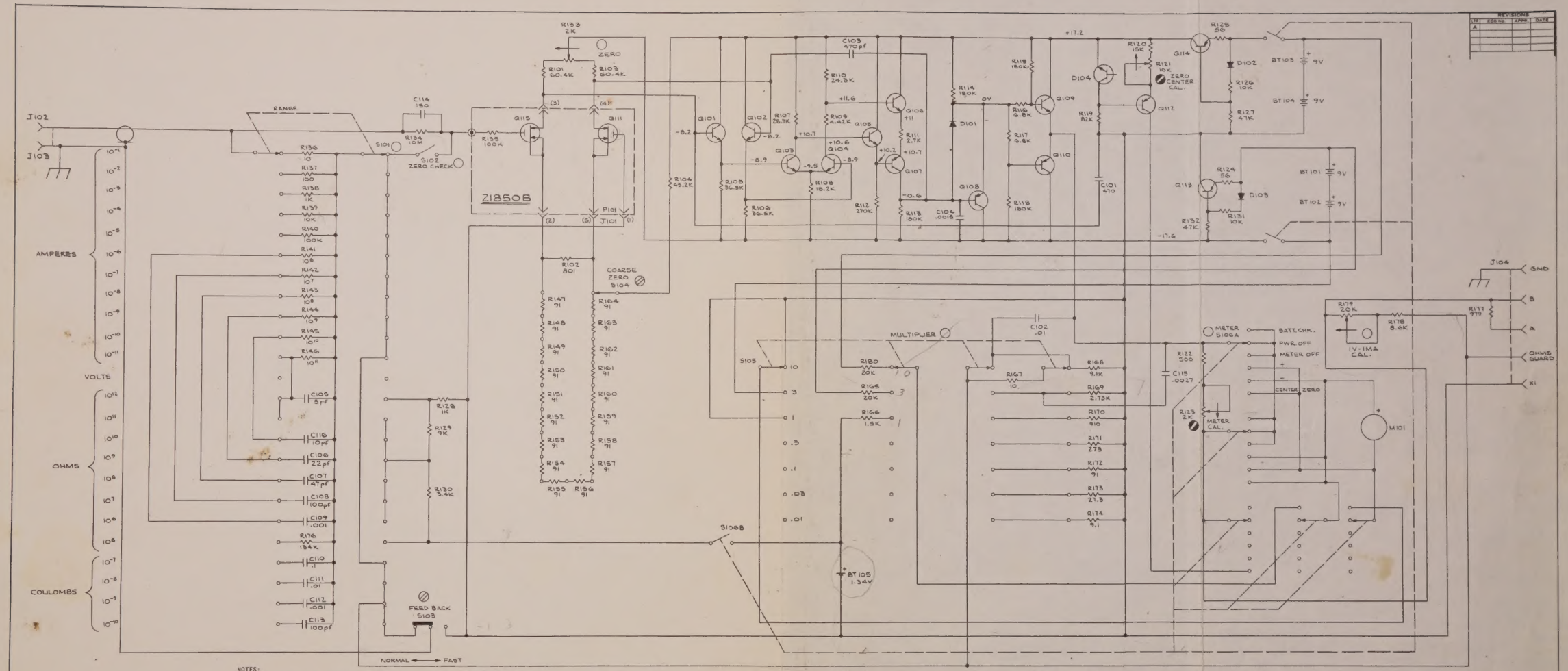



FIGURE 12. Diagrams of Model 600B as Peak-reading Voltmeter. The Model 600B is used on its COULOMBS ranges. The diode is external to the voltmeter. C is the capacitor selected with the Range Switch; $R_i$ is the Model 600B input resistance. Accuracy of the measurements depends mainly upon the quality of the diode used.

## SECTION 4. CIRCUIT DESCRIPTION.

4-1. GENERAL.

a. The Keithley Model 600B is basically an extremely stable and linear dc voltmeter with a full-scale sensitivity of 1 millivolt and an input impedance of $10^{14}$ ohms shunted by 20 picofarads. By using the front panel controls, shunt resistors and capacitors are selected to make measurements over a total of 72 voltage, current, resistance and charge ranges. Current and resistance are measured using precision




NOTES:

1. ALL RESISTANCE & CAPACITANCE SHALL BE DESIGNATED IN OHMS & MICROFARADS UNLESS OTHERWISE NOTED.
2. ◯ FRONT PANEL CONTROL.
3. ◑ INTERNAL SCREWDRIVER ADJ.
4. ⊘ REAR PANEL CONTROL.
5. M MEGOHM
6. K 1000 OHM
7. pf PICOFARAD
8. ✳ INDICATES NOMINAL VALUE DETERMINED DURING FINAL CALIBRATION.
9. ↑ CLOCKWISE ROTATION.
10. ALL VOLTAGES MEASURED REFERRED TO CHASSIS GROUND, WITH S103 IN NORMAL.

| HIGHEST SCHEMATIC DESIGNATIONS | | | | |
|---|---|---|---|---|
| M101 | BT105 | D104 | R180 | C116 |
| Q115 | S106B | J104 | P104 | |

| SCHEMATIC DESIGNATIONS NOT USED | | | | |
|---|---|---|---|---|
| | | | | |

PRELIMINARY
FOR ENGINEERING USE

600B
MODEL | NEXT ASSEMBLY | USED ON

| DIMENSIONAL TOLERANCES UNLESS OTHERWISE SPECIFIED | | | |
|---|---|---|---|
| FRAC. | DEC. | ANG. | |
| ± 1/64 | ± .005 | ± 1° | |
| DO NOT SCALE | | | |

DRN. D.D.L. DATE 6-15-68
CKD. BB DATE 8-1-68
ENG. APPR. MA DATE 8/1/68
PILOT RELEASE DATE
PROD. RELEASE DATE

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CLEVELAND, OHIO

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FINISH

TITLE
SCHEMATIC
ELECTROMETER

DWG. NUMBER
22808E

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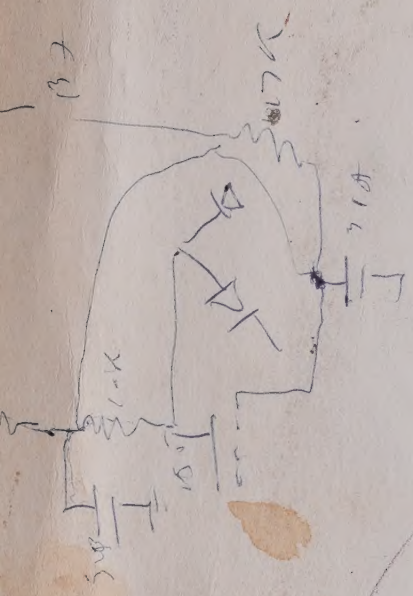

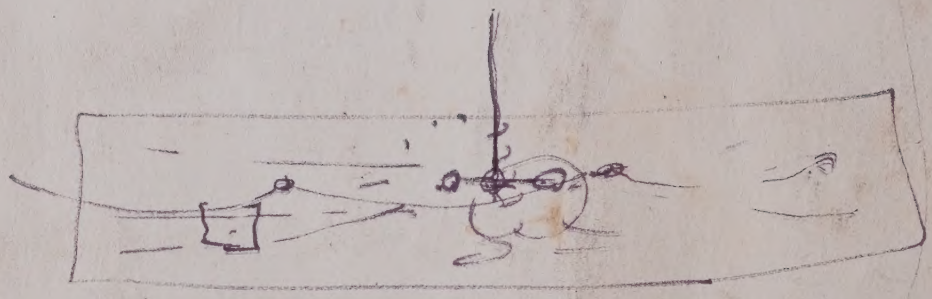

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